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HYDROGRAPHIC SURVEY OF THE SHORT-TERM ANCHORAGE AREA (DW 2)

A report submitted to the Directorate of the
North Sea of the Ministry of Public Works - Rijkswaterstaat.

By Joseph Entsua-Mensah
3rd June 1994

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RIJKSWATERSTAAT
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Appendix I Literature

Summary

This report has evolved from my participation in the hydrographic surveying on board m.v. Zirfaea of a section of the Kort Verblÿfzee Anker Gebied(Short-Term Anchorage Area).
I have tried to describe the process of data gathering and post-processing of collected data needed for the construction of depth charts or nautical charts.
Essentially, data collected are: depths(soundings), positions,and tidal levels of the same day of the sounding campaign.
Depths are measured with echo sounder which may be single or multiple beam, whilst position may be obtained using position fixing systems like the Hi-fix, or recently by satellite methods of which DGPS is fashionable. Tidal levels may be achieved directly from a sea-bottom tide gauge deployed in the vicinity of an offshore work area or indirectly from a permanent, primary tidal station by the use of a co-tidal chart and tidal levels from the primary station.
These data, positions, tidal information, depths and time are logged to a disk which are subsequently loaded to a computer in the office for processing. The processing involves applying tidal corrections, barcheck correction and correction due to squat. Depth biasing is also made due to the fact that the large volume of data collected cannot all be repesented on a chart. What depths are selected for presentation depends on the intended use of the chart. For example, for charts required for navigation, it is important to show shallower depths. Charts required for volume computation after dredging operation show besides the shallower depths, also the deeper depths. The processing may also involve editing where data may be added or subtracted as the situation may demand.
Depth charts may contain only "matrixed depths or "matrixed" depths and contours.
The North Sea Directorate uses Nesa PDS-1000 for data acquisition as well as for processing.

1.0 **Introduction**

This area internationally described as "short-term" anchorage area (DW2) is of immense importance when it comes to anchoring of deep-draugth vessels; deep-draugth vessels heading for the Port of Rotterdam via the Euro Channel anchore here until the tide is at a high ebb before continuing their journey.It stands to reason that this area is frequently surveyed to ascertain safe depth.
The main task of hydrographic surveying is the measurement of water depths.In order to achieve this,time, position, depth must be measured at the same time.These measurements are made continuously with a survey vessel sailing along pre-determined tracks called sounding lines.Other tasks in hydrographic surveying are current measurements,sea bottom sampling,density measurements (ie determination of Nautical Bottom),delimitation of special harzards to navigation,fixing of Navigational Aids(Navaids) e.g. buoys.

2.0 **Depth Measurement**

2.1 Sounding Instrumention

Sounding is the determination of water depths.In the begining this was achieved by means of the lead-line which consist of a graduated wire or thread at one end of which is attached a load.In order to measure the depth,it is lowered gently until it just touches the bottom; the level of the water is then read on the wire.Though this traditional method is now widely replaced by faster,more convenient methods using acoustive wave (echo sounding),it is still the more favoured practice when it comes to surveying areas of very shallow water and in the close vicinity of harbour or port structure where survey boats run the risk of grounding or being damaged.

2.2 Principle of the Echo Sounder

An echo sounder consists essentially of three parts namely:
- A transmitting unit with a signal generator that produces an electrical pulse that is sent to the transducer which then transforms the electrical pulse to acoustive sound pulse.
- A receiving unit with another (or the same) transducer that transforms the received acoustic pulse to an electrical pulse.The pulse is amplified and sent to a registration unit.
- The registration unit which consists of a direct current motor, constantly turning a stylus that burns the paper when it receives the electrical signal.The acoustive pulse from the transducer is projected through the water to the seabed and the time interval between the transmission of the pulse and the reception of the same pulse reflected from the seabed is

converted to distance (depth) and presented on a trace of paper.This is the principle of all sonars ; an echo sounder is simply sonar (**S**ound **N**avigation **A**nd **R**anging) with a beam fixed in a vertical axis.An echo sounder measures time (between transmission and reception of pulse) and converts this to range by multiplying half the time (the pulse makes a two way journey) by the velocity of sound in water, thus;

Depth = 0.5 * v * t

where t = time taken for sound pulse to travel to the seabed and back.
v = velocity of sound in water.

It is important to stress here that an echo sounder does not, and cannot measure depth.All sounders measure time which is then converted to depth.

2.3 Echo Sounder Errors

A well adjusted echo sounder must be properly calibrated before the apparent depths recorded by it will approximate to the true depths.To obtain true depths, various corrections must generally be applied to apparent depths.Some of these correctons can be calculated or practically determined whilst others can only be estimated.It is fashionable nowadays for instrument makers to incorporate some of these corrections in the manufacture of echo sounders so that in its use they are no more accounted for.
There are several errors that can affect depth measurements.These include:
- Index error.There is an index error when the transmission line on the paper does not correspond to the transducer draft.
- Squat means a change in a vessel's trim when it is under way.This error is minimised if transducer is fixed to the trimpoint of the vessel.
- Settlement.This causes the water level around a vessel under way to be lower than when it is stationary.This makes measured depths lower than would otherwise be the case.The correction which is additive may be physically determined and applied to all measured depths. It depends on depth, hull shape and speed.It will usually be insignificant if depth > 7 * draught.
- Separation error.If separate transmitting and receiving transducers are used and there is a horizontal displacement between them,then errors are introduced which may be significant in shoal waters.Simple Pythagoras theorem shows that :

$$\text{Error} = r - \sqrt{(r^2 - s^2/4)}$$

where r = apparent depth below trasnducer
s = horizontal separation.

- Sound velocity.The most important thing in using an echo sounder is setting the correct value of the speed of sound.Sound velocity is a function of salinity,temperature,and depth. More important are the first two.These sound-velocity- depen-

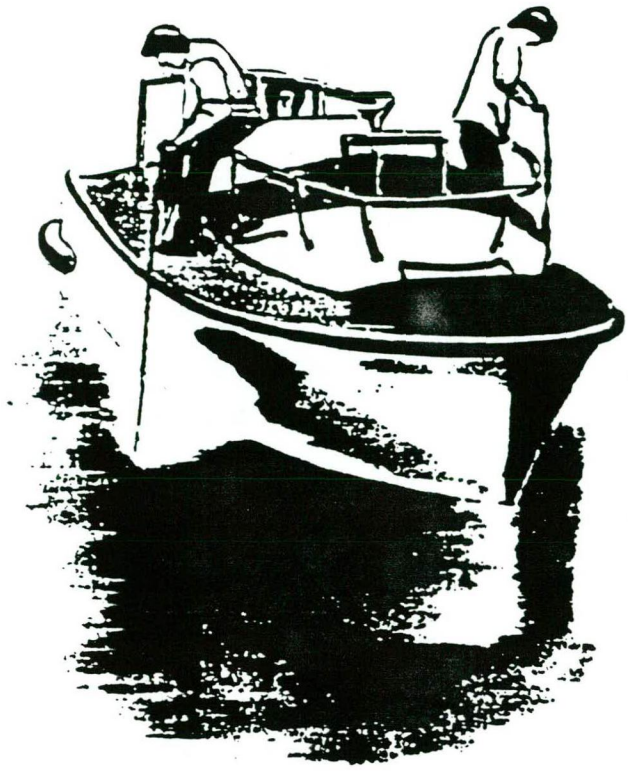
dent parameters vary with the seasons and in different water conditions.Consequently it is neccessary to calibrate the echo sounder to determine the correct value of the sound velocity before and after the sounding campaign.

2.4 Calibration

With for example, the "Beckman salinometer" it is possible to measure the conductivity(related to salinity) and the temperature at certain depths.The sound velocity is then calculated by empirical formulars.Sound velocitimeters which measures the velocity of sound directly may be used.
The usual practice on most vessels is to use the barcheck. This is a T- or V - shaped piece of steel or alumininium(width of T-bar or opening of V approximately 20 cm);Its length is a little more than the width of the survey launch.To its ends, thin plastic-coated stainless steel wires which are marked every two meters are attached.The bar is lowered into the water and held below the transducer.The speed of sound is adjusted so that the trace created by the calibration bar on the echogram coincides with the depth the bar is held at.This is repeated with different depths (with an interval of say two meters) to determine that the sound velocity is not changing too much in the water between the surface and the bottom.See fig.2.4

2.5 Depth Measuring System on m.v. Zirfaea

Two systems are available for measurement of water depths.These are:
- Simrad EM 100 Multibeam Echo Sounder System.The Simrad EM 100 is a shallow water precision seafloor mapping system, providing both topological maps and acoustic sonar imaging(optionally) of the seabed in the same operation.The instrument is suitable for : a) Hydrographic charting of navigation lanes, and coastal areas. b) Geological mapping and scientific investigations. c) Location of objects on the seafloor.
- Atlas Deso 25.This is a single beam two-frequency survey echo sounder which can be used as a single unit and also as part of an automated survey system for all fields of application in hydrographic surveying.For a differentiated display of bottom layers having different densities, e.g. silt detection in fairways,for distinguishing between sediments and for locating wrecks, pipelines and cables, it is practical to use a sounder which works with two frequencies simultaneously.This type of sounder makes use of the differing characteristics of different frequencies: high frequencies are completely reflected at the silt/water boundary layer; low frequencies, on the other hand, penetrate into the silt and produce echoes at the silt/bottom boundary layer and at the various sediments.See appendix G for some technical data.



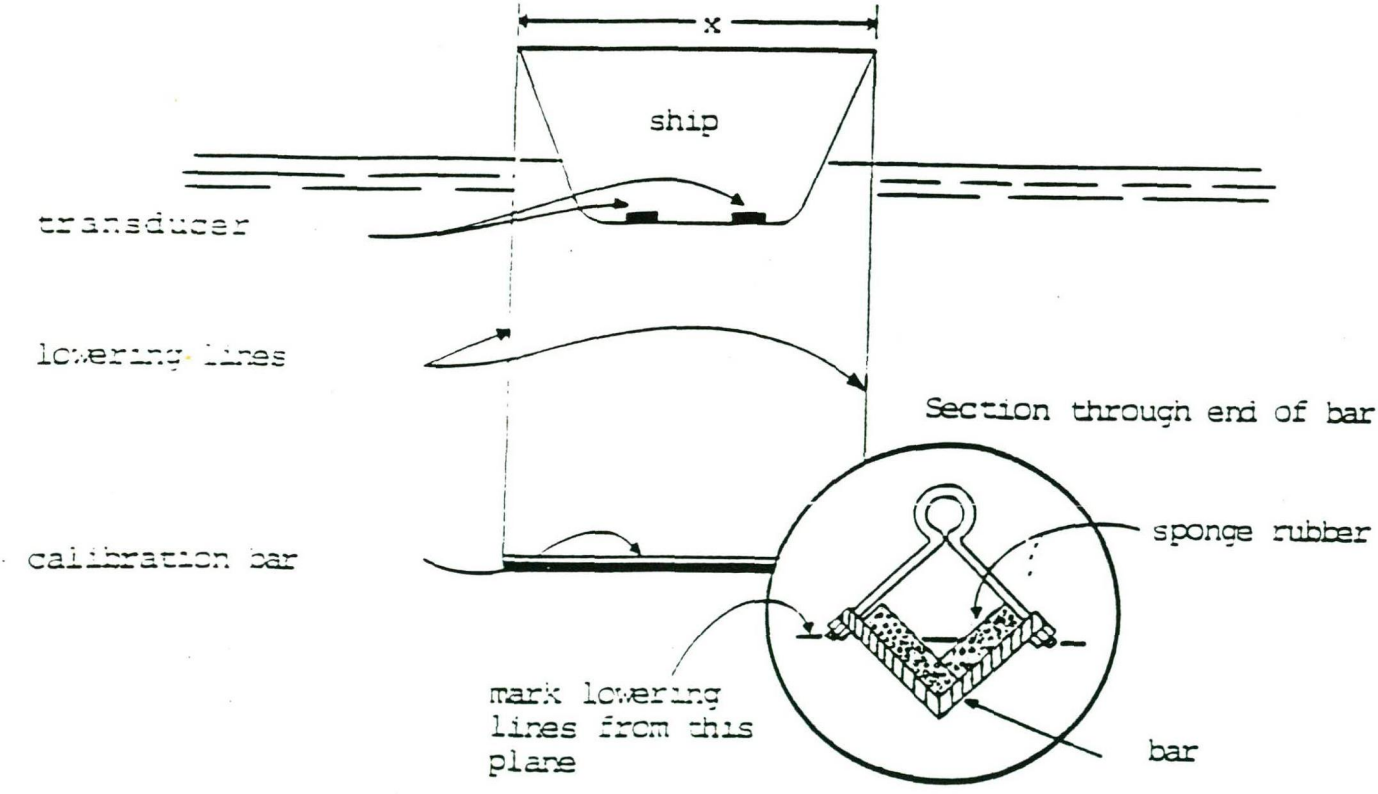


Figure 2.4 Barcheck Calibration

3.0 **Position Fixing Afloat**

The position of a vessel at sea and hence of soundings(obtained by the intersection of lines of position-LOPS) may be achieved by a number of ways.There are the obsolete traditional methods and the modern conventional methods which are hinged on electromagnetic waves.

3.1 Direct and Visual Traditional Methods

Some of these methods are:
- The method of Forward Intersection.Here a theodolite or sextant is set up on two known points ashore.Simultaneous measurement of the angle of the two directional lines to the survey ship is made.The intersection of these two lines gives the position of the ship.See fig.3.1.
- Resection method.Two people on board the ship observe simultaneously, horizontal sextant angles to obtain a fix. As the surveying proceeds, the position of the ship is continously plotted with a station pointer to see if the ship is fairly accurately following the prescribed sounding line.

3.2 Electronic Position Fixing(EPF)

It is fashionable nowadays to fix the position of vessels by location systems using electromagnetic waves. These systems may be classified according to the fix configuration or what wavelength or frequency they use.

3.2.1 Classification by Frequency

Classication of EPF systems in terms of their frequency band lends itself to the characteristics of the system,e.g.higher frequencies are associated with short ranges.By this classification systems may be called :
- High frequency systems.These are used for precision navigation.The range is only 20-30km, but under favourable conditions, distances of the order of hundreds of km may be realised.The main sources of errors are reflections from the earth surface which leads to cancellation of signals which also results in **dead zones** where no position can be found.This phenomenon is called range-holes or dip-zones and is caused by reception of signals travelling a direct and others traveling a deflected path;interference of these signals may then lead to disturbed or impossible reception.This difficulty may be overcome by using double antenae of different heights.Automatic switch over is effected in instances of range-holes.The acuracy is quite variable but is normally between 10 and 20 meters under good conditions.
- Medium frequency systems.These systems are the ones usually

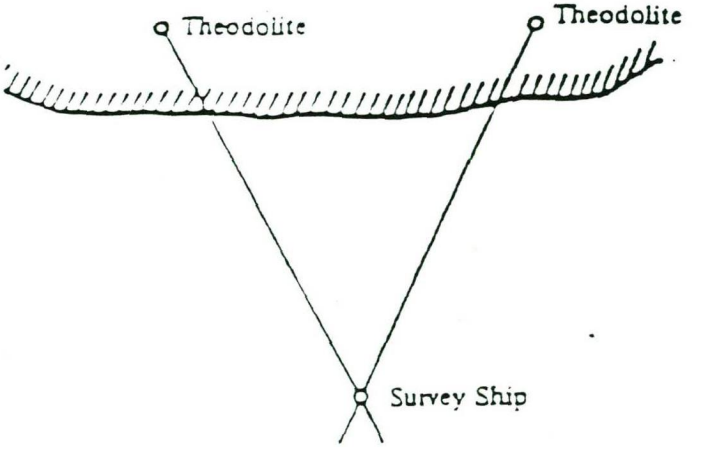


Figure 3.1 Method of Forward Intersection

used for hydrographic work.Hyper-fix is one of such systems.Have range up to 800km approximately(typically 200km), but this is possible only in day times. At night measurements are susceptible to skywaves,(wave reflections from the ionosphere).
- Low frequency and very low frequency systems.These systems are for general navigation and ocean-wide hydrographic work.Amongst the very low frequency systems,the Omega is the most important.This system has a world-wide coverage but the acuracy is not better than a few kilomters.With the low frequency, the range can be up to one or two thousands of km and the acuracy under good conditions can be about 30 meters.sources of error are as for medium frequency systems.
- Satellite systems. Of these Global Position Systems(GPS) and Differential Global Position systems (DGPS) are the ones used for hydrographic surveying.GPS offers a 3-dimensional instantaneous fix at intervals of a few seconds by measurement to four satellites,fig.3.2.Three ranges made to three satellites are sufficient, but a third measurement is necessary to resolve the clock drift error.For a moving ship the acuracy is between 10 and 100 meters.For enhancement of GPS acuracy it may be modified into DGPS.This is done by reading the system transmissions at known points onshore (ie monitor stations),thus obtaining the difference between the absolute and system position 'offset'or correction.This correction is then transmitted to DGPS receivers.

3.2.2 Classification by Fix Confuguratiion or Line of Position

By this classification location systems may be considered to be operating in **cicular** mode and **hyperbolic** mode.
- Cicular mode.In this mode a point whose position is required is determined by thee intersection of two distance circles obtained by distance measurement carried out between a survey ship and a pair of fixed radio stations at known positions on land.For fixing positions by the circular method,two cicular lines of position are necessary, which requires two pairs of **master-slave** stations.The master station corresponding to each slave station is set aboard the ship (the mobile) so that a single master station is often used as common to both pairs, partly though.See fig 3.2.2
- hyperbolic mode.Mathematically, the locus of a moving point at which the difference between distances from the moving point to two fixed points is constant is called a hyperbola, and the two fixed points are called focuses;thus a hyperbolic line of position is that whose difference in distance to two known stations is always constant.The principle is that, three shore stations - **master, slave 1, slave 2** are deployed ashore as illustrated in fig 3.2.2.The receiver aboard the mobile detects either the differences of phase or time or distance and converts these differences into lopes.A fix is obtained by the intersection of lopes generated by master-slave 1 and master-slave 2.

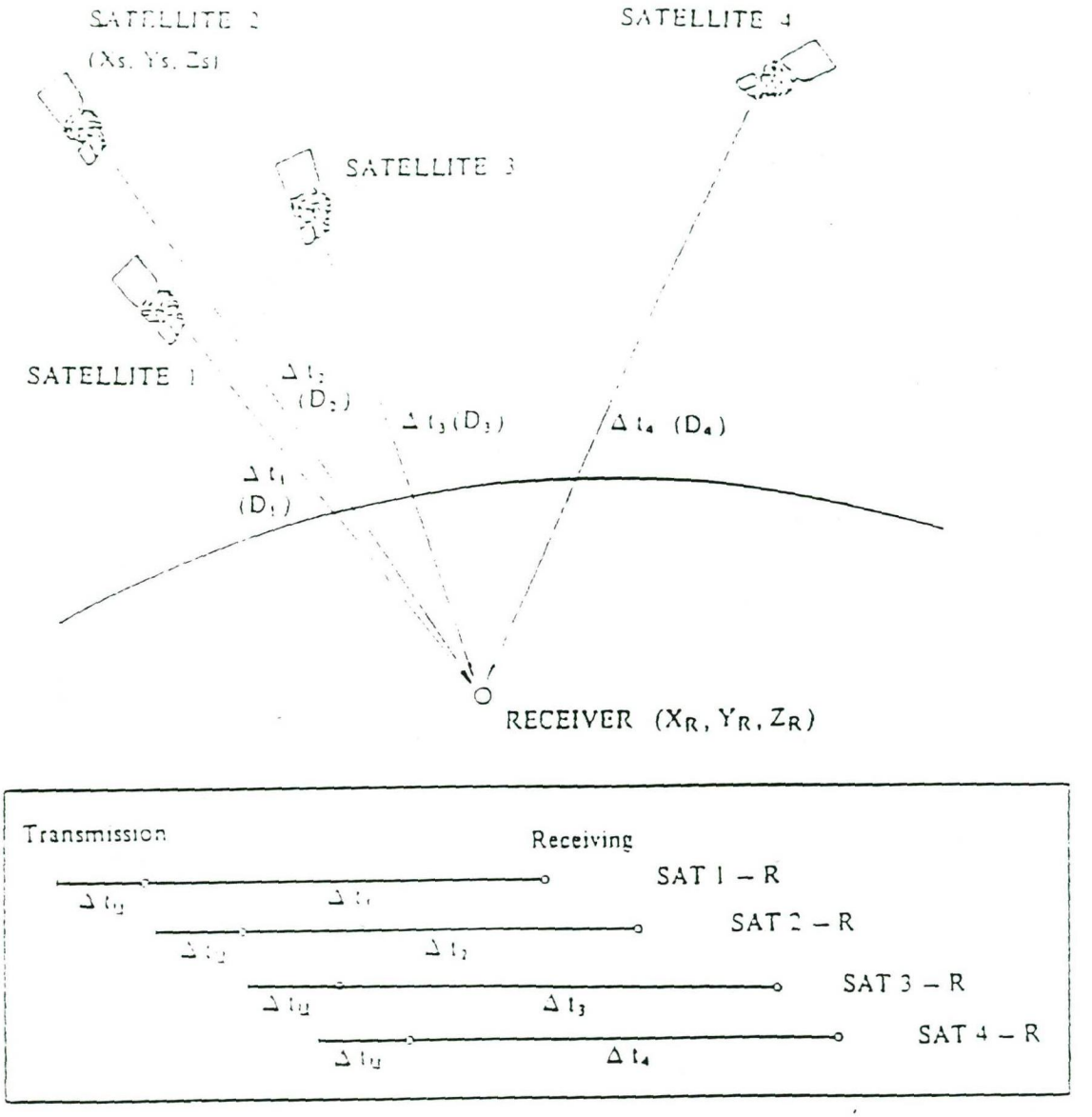


Figure 3.2 Measuring Principle of GPS

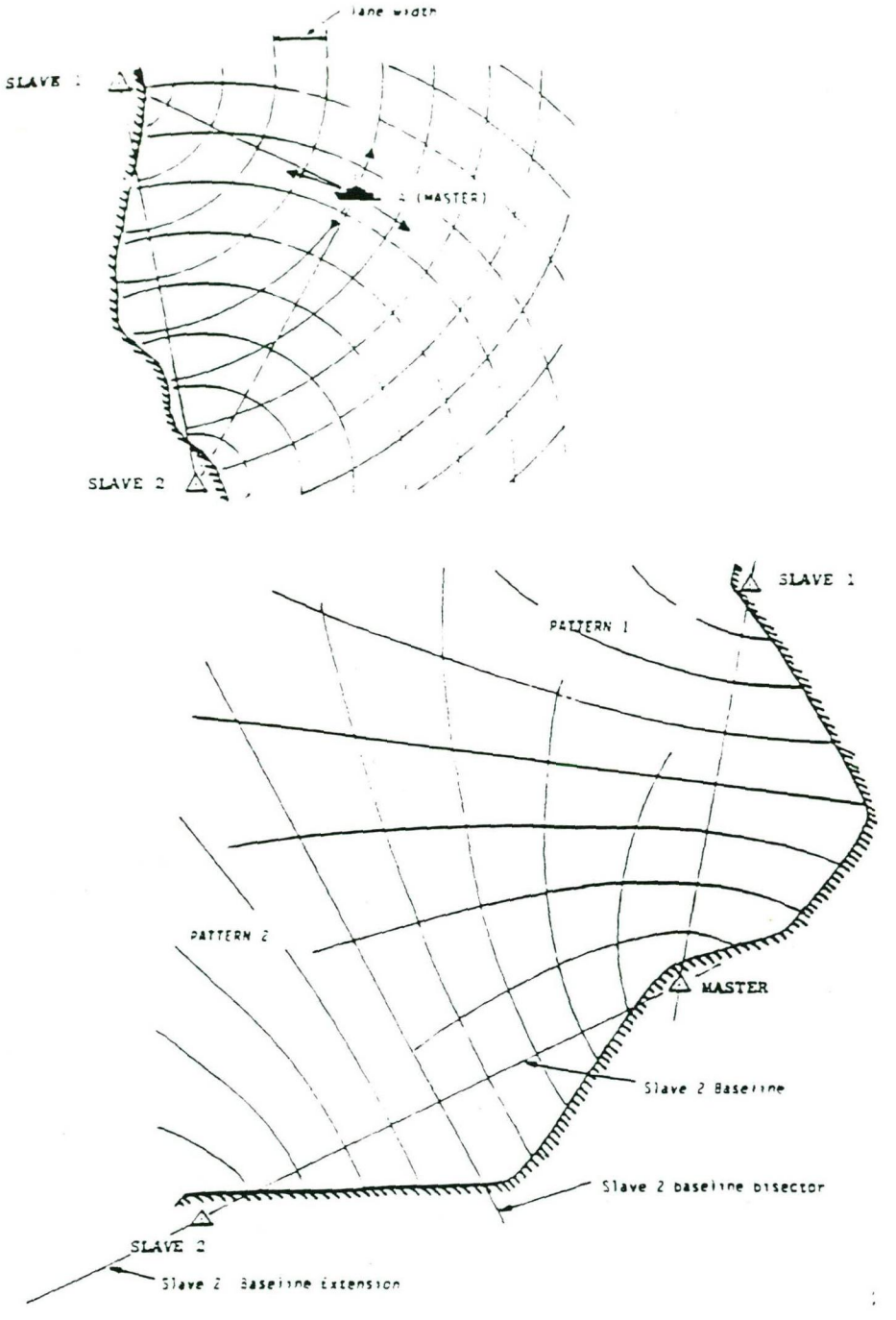


Figure 3.2.2 Circular(top) and Hyperbolic(bottom) Modes of Operation

M.V.Zirfaea uses Hi-fix(hyperbolic system) and DGPS for positioning.The DGPS co-ordinates are the ones used for chart making and are refered to as primary co-ordinates whilst the Hi-fix co-ordinates are called secondary.

4.0 **Concept of Tides**

4.1 Definition and Basics of Tides

The tide is a periodic vertical movement of the sea.This movement is a consequence of the gravitational forces of the sun and the moon and the revolution of earth/moon and earth sun systems.This is called gravitational tide and is the largest contributer of any observed tide.Another type of tide, meteorological tide, generated by meteorological forces exist, though insignificant compared to the contribution made by gravitational attraction.The meteorological tides are usually caused by sudden changes in air pressure between different places of the watermass which results in different water levels.Due to effects of inertia and friction, the water level will not adjust itself immediately as the pressure changes.Thus a tide wave is set up when there is a movement of water mass from a high pressure area to a low pressure area Waves are also created by the wind that piles up water masses (especially against the coastline).These waves may be combined with meteorological tide waves to form larger waves.When a wave travels into shallow water, its shape is changed; this can be seen when waves runs into a shelving beach.This phenomenon is called shallow water effect.Shallow water effects sometimes produce unusual anomalies, such as unequal periods between high and low water.

4.1.1 Physics of Tides.

According to Newtons's law, the gravitational force between two bodies, e.g. earth and moon is proportional to their masses, and inversely proportional to the square of the diatance between them.It is expressed by the equation:

$$\textbf{Force} = G * m_e * m_m/R^2$$

where **G** is the universal gravitational constant, m_e is the mass of the earth, m_m is the mass of the moon, and **R** is the distance between them.
Revolution of the earth/moon system introduces centripetal force.The horizontal component of the difference between the gravitatinal and the centripetal force is the tide driving force.These **horizontal tidal tractive forces** are very small and are inversely proportional to the cube of the distance between the moon and the earth, but because they are not balanced they cause the water movement.Their distribution on

the earth's surface is shown in fig.4.1.1
The pattern of these tide-producing forces produce bulges of water over the areas on the near and far sides to the moon where the forces are directed outward from the earth's surface,but depressions between these areas where the forces are directed inward.Fig.4.1.1 If we now introduce the rotation of the earth about its polar axis,each point on its surface will pas through the whole pattern of forces in one day, with two passages under the bulges and two under the depressions.This is the basis for existence of semi-diurnal tides on a diurnally rotating earth.

4.1.2 Determining the character of the Tide

There are mainly two types of tide.These are semi-diurnal tides with two low and high water per day and diurnal tides with one high and one low water per day; the heights of subsequent high/low warters will normally differ considerably.(fig. 4.1.2).It is also possible to have mixed tides of semi-diurnal and diurnal.
In the analysis and prediction of tidal movements, mathematicians use different fomulæ, depending on whether the tide is 'mainly semi-diurnal' or 'mainly diurnal'.The surveyor who often obtains the observations which must be analysed,must therefore know how to distinquish between these two types of tides.
In most cases he will be able to determine the character of the tide merely by studying the tidal curve,its mainly semi-diurnal or diurnal may be obvious.Where doubts exist, the following formulæ have been devised to provide working criteria;they depend on the amplitudes of some of the harmonic constituents of the tide in question:

(a) If π(H of S_2) is greater than 2(H of K_1 + H of O_1) the tide is 'mainly semi-diurnal'.
(b) If π(H of S_2) is less than 2(H of K_1 + H of O_1) the tide is 'mainly diurnal.

4.2 Tide Recording

The tide is recorded by means of the tide gauge, which may be either non-registering or registering, the distinction being whether an observer is required or operation is automatic.
The North Sea Directorate has a permanent and primary tidal station at the Europlatform.Here the gauge is self-registering and the level of the water is recorded every 15 minutes.In the instance where the work area is very far from this primary tidal station, a registering Dag 6ooo Bottom-Tide-Gauge is deployed in the vicinity of the work area.

4.3 Application of Tides.

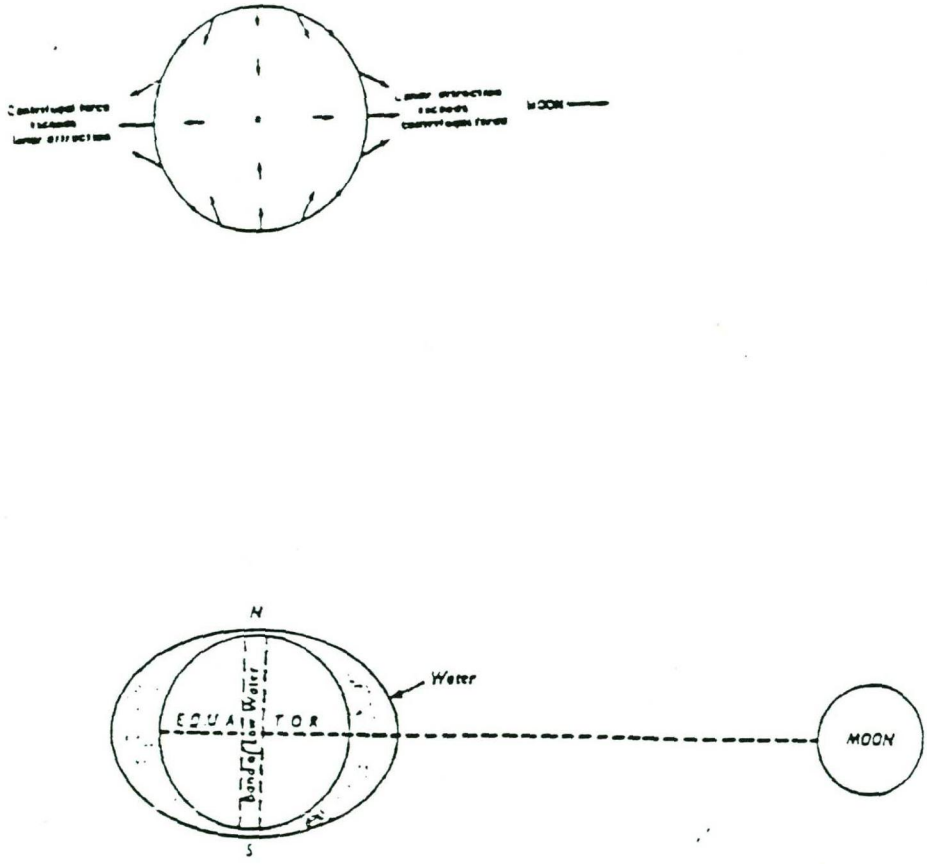


Figure 4.1.1 Distribution of the Horizontal Tidal Tractive Forces(top) and Tidal bulges - semi-diurnal Tide Generation(bottom)

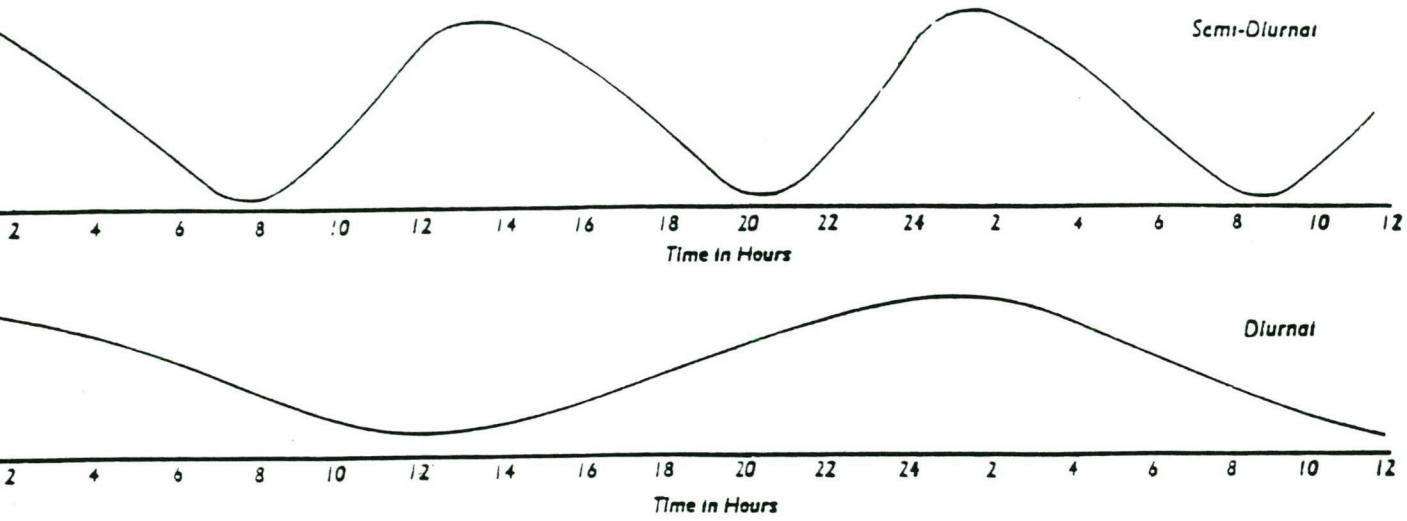


Figure 4.1.2 Typical Semi-Diurnal and Diurnal Curves

Depths on charts are referred to the so-called chart datum, which is an arbitrary level plane so chosen that the actual depth will not at any time be less than the depth shown on the chart.The water surface seldom coincides with the chart datum and in order to bring the measured depths to this reference plane they must be corrected for the height of the tide.A tidal correction curve is usually constructed for this purpose.
At greater distances from the gauge, the amount of reduction can no longer be taken from the graph as the status of the tide at the gauge and at the survey location will differ too much.In this situation a co-tidal chart in conjuction with tidal levels at a primary station may be used in obtaining the tidal reduction curve for the work area.

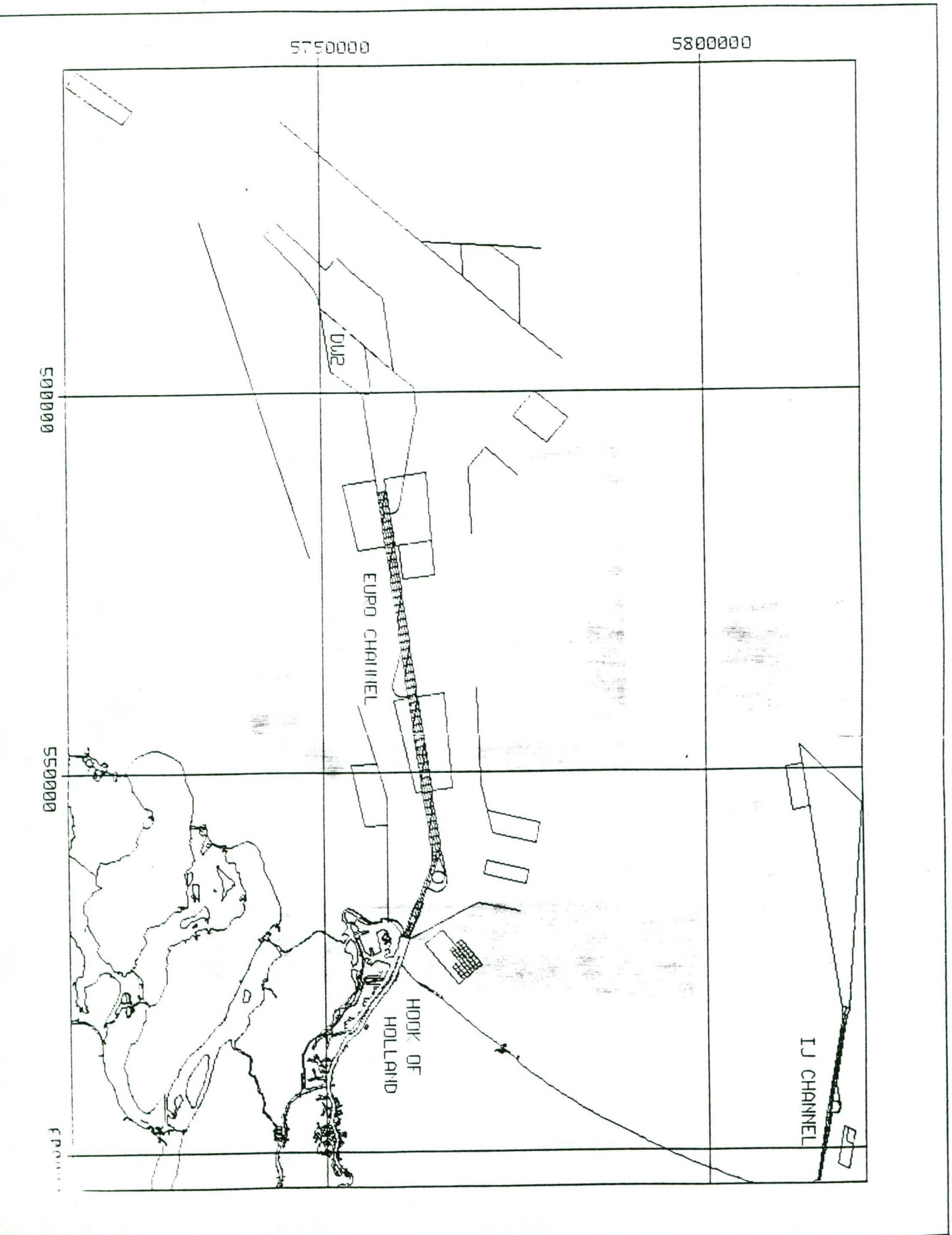
5.0 **Data Logging and Data Proccessing**

On m.v. Zirfaea, data is acquired with a NESA-PDS 1000 system.The same system is used in the post-processing of the data.The system software contains three major modules:
- The On-line Module.This has submodules namely Confuguration, Parameter Input, Survey, Dredge, etc.The On-line menus are modules related to the setting up of the software and the actual collecting of survey or dredge data.To get On-line (doing a real survey or dredge operation), it is necessary to go via the Configuration Module(setting up the hardware), the Parameter Input Module, (manually entering the Survey or Dredge parameters) to either survey or dredge.The Survey and Dredge Modules use data from previous modules(Configuration and Parameter Input) for navigation, and generate Raw Data Files that are used in the of-line modules.
- The Off-line Module.Correction, Edit, Plot, Matrix, and Profile are the submodules of this module.This module is essentially for processing, ie to apply correction to the collected data, and to plot these data on a plotter.The corrections usually applied are the height of the tide, bar check, and squat.
Matrix Module creates a matrix from a corrected survey data for the purpose of computing for e.g. volumes and creating contours.
- The 'Other' Module gives the user a choice of utilities for manipulating data and data bases.

Appendices

Appendix A

Overview of DW 2



Appendix B

Corner Co-ordinates of DW 2

	UTM		GEOGRAFEN	
NR.	EASTING	NORTHING	BREEDTE	LENGTE
610	500000.000	5756791.130	51 57 38.67 N	3 0 0.00 O
606	493725.890	5755908.940	51 57 9.98 N	2 54 31.35 O
607	488620.480	5750040.520	51 53 59.75 N	2 50 4.62 O
608	497133.800	5751333.320	51 54 41.98 N	2 57 30.00 O
609	500167.950	5755598.510	51 57 0.07 N	3 0 8.80 O

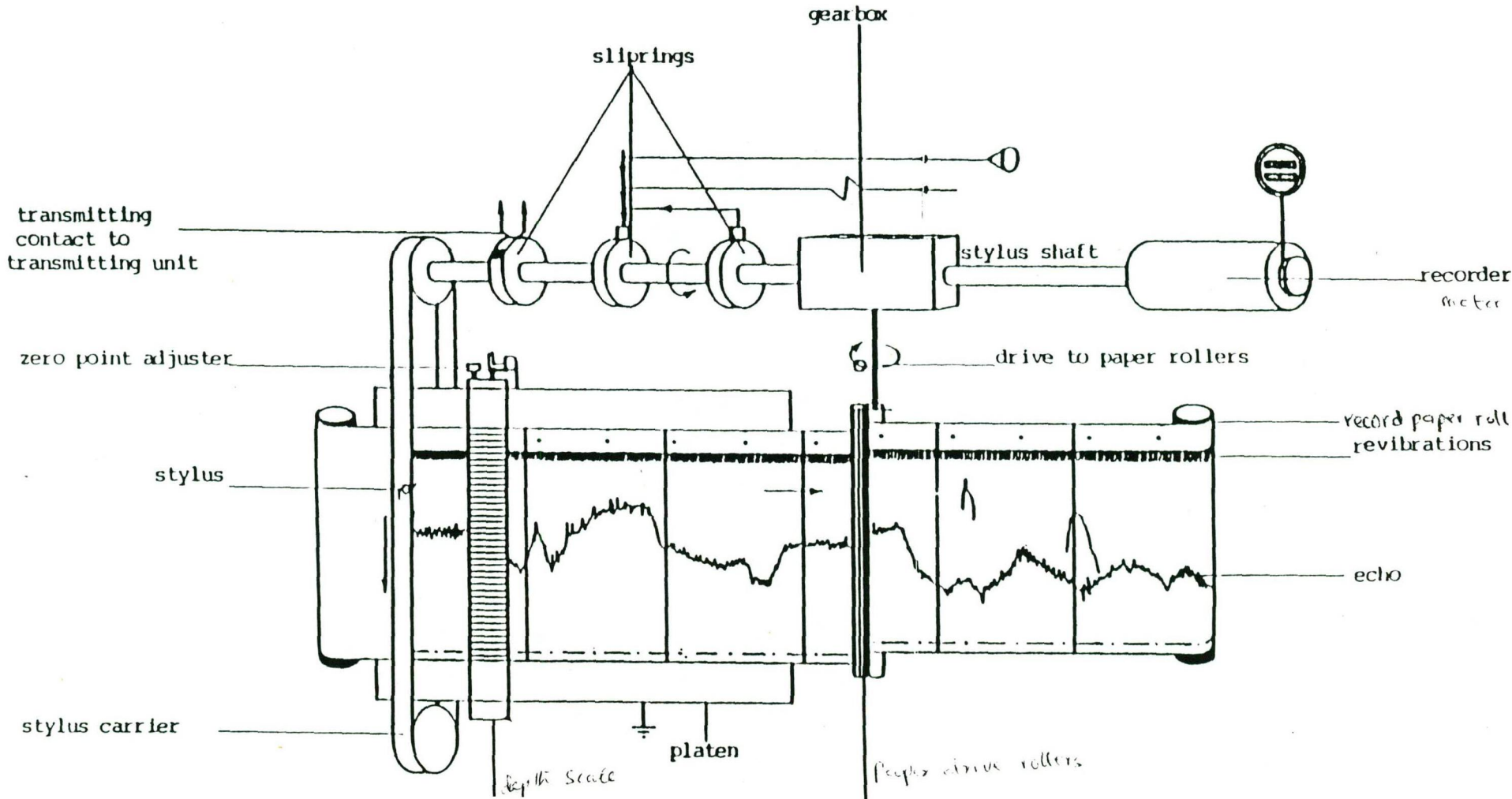
****

vlakte = 39.70 km.

fstand 50 m totale raaiafstand : 794 km.
fstand 100 m totale raaiafstand : 397 km.
fstand 125 m totale raaiafstand : 318 km.

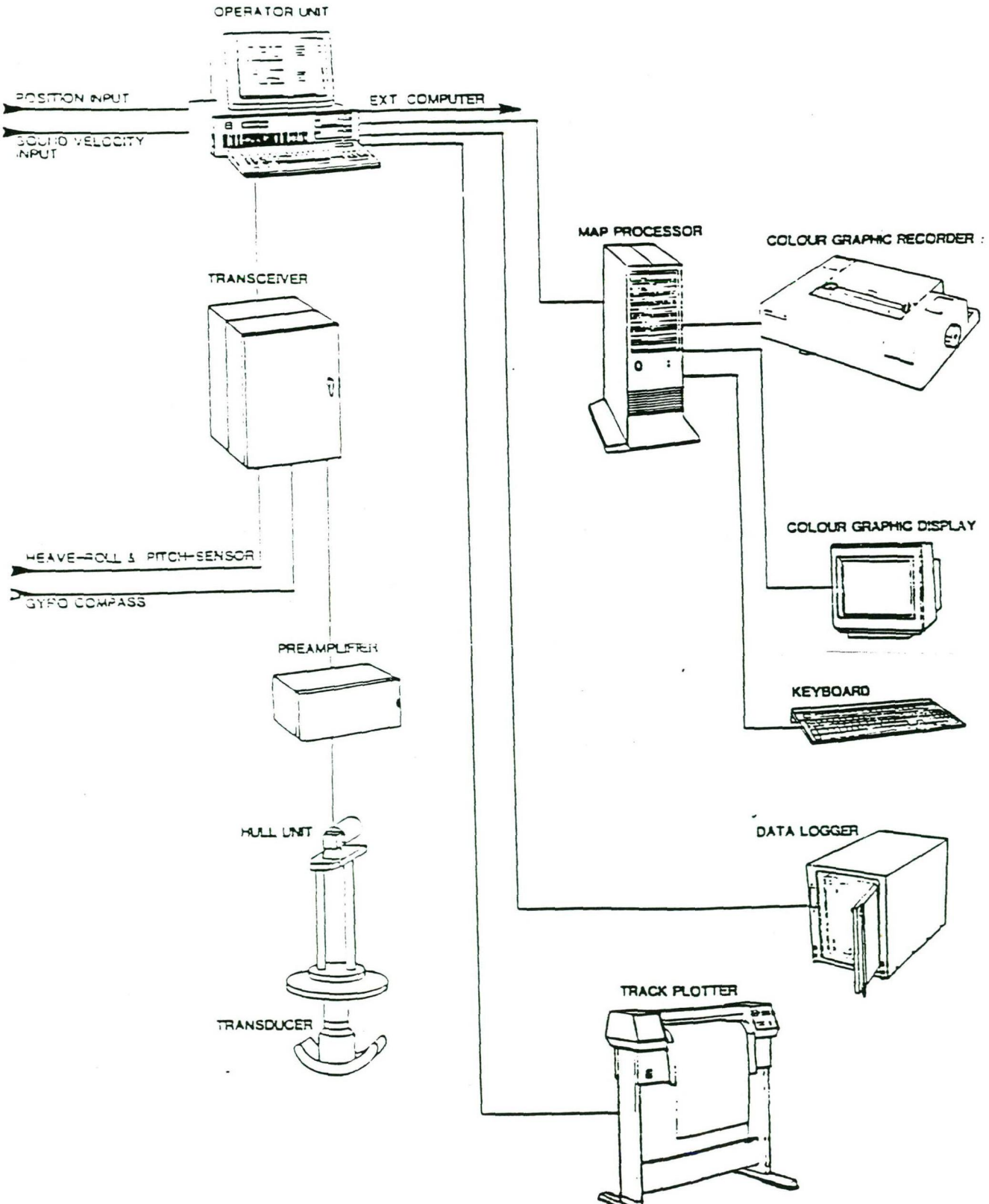
Appendix C

Principle sketch of an Echo Sounder



Appendix D

Simrad EM 100 System Diagram



Appendix E

Simrad EM 100 Technical Specificaions

TRANSDUCER

Curvature:	45cm
Number of elements:	96
Sector of elements:	120 degrees
Stabilization:	Mechanical against pitch

TRANSMISSION

Frequency:	95 kHz
Source level:	225 dB rel. 1µPa at 1 m
Pulse length:	0.2 or 0.6 ms
Repetition rate:	4 Hz (max.)
Beamwidth	
Fore and aft:	Corresponding to total receiving sector
Athwartships:	or alternating between smaller sectors.
Number of power amplifiers:	96

RECEPTION

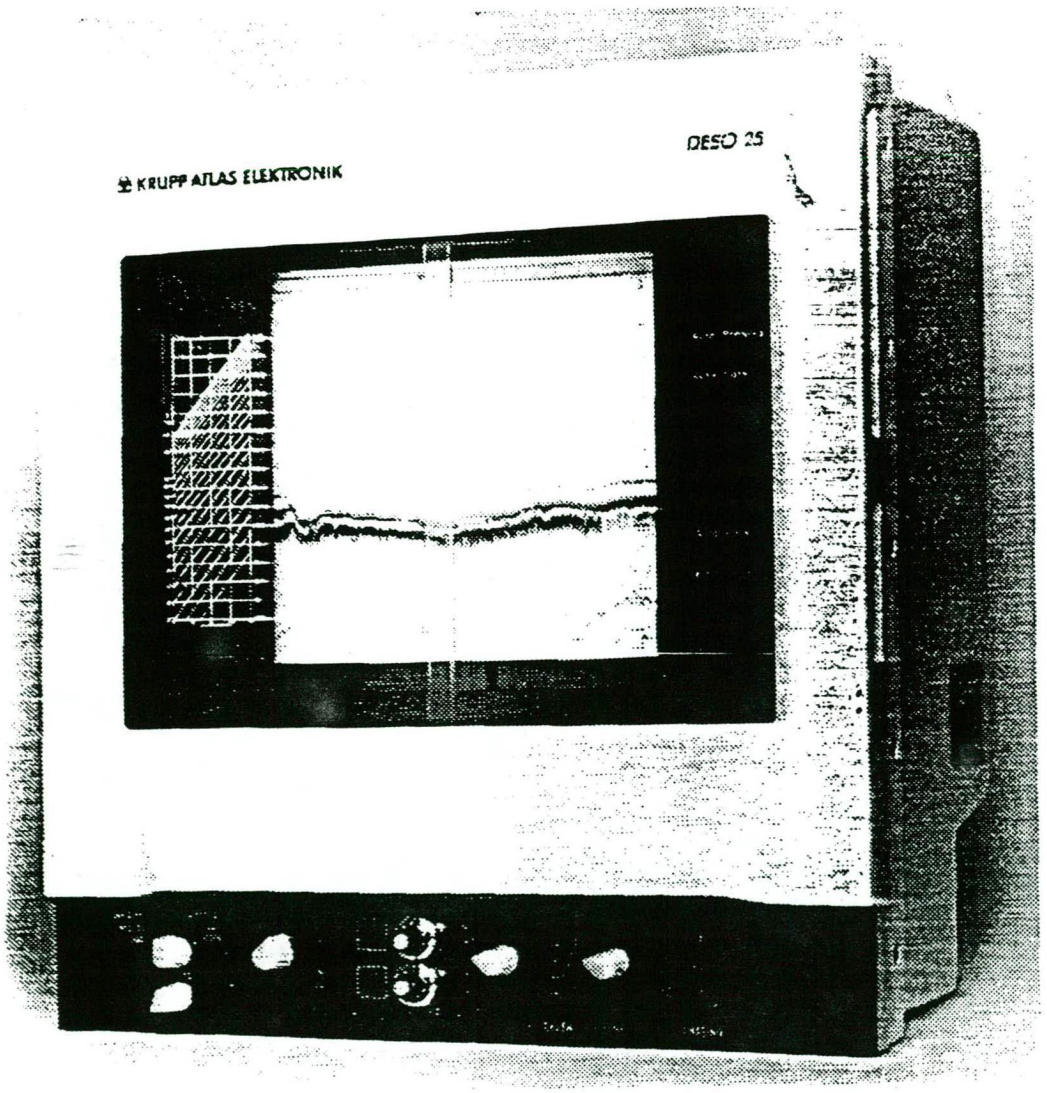
	WIDE	UWIDE	NARROW
Total sector (degrees)	80	100	40
Number of beams	32	27	32
Beamwidth transverse (degrees)	2.5	5.5	2
Total sector reduces when roll exceeds (degrees)	2.5	11.25	±15
Beam spacing (degrees)	2.5	3.75	1.25
Transverse coverage	1.7 d	2.4d	0.73d
Beamwidth fore and aft (degrees)	3	3	3
Sidelobe level (dB)	18	18	18

DEPTH ACCURACY AND RESOLUTION (HORIZONTAL BOTTOM)

	WIDE	UWIDE	NARROW
Resolution 7.5 cm at depth	<62m	<53m	<124m
" 15 cm if variation	>82m	>82m	>82m
" 15 cm at depth	<124m	<106m	<248m
" 30 cm if variation	>164m	>164m	>164m
" 30 cm at depth	≥124m	≥106m	≥248m
" 45 cm if variation	>328m	>328m	>328m

Appendix F

Two-Frequency Survey Echo Sounder, Atlas Deso 25



Appendix G

Some Technical Data of Deso 25

DIMENSIONS

Height	488 mm
Width	440 mm
Depth	270 mm
Weight	26 kg
Installation	Bulkhead, console, 19" in equipment cabinet

OPERATING VOLTAGES

Rated voltage:	24 V +30 % / -20 % DC
Brief overvoltage:	60 V ≤ 1 ms
Starting current:	10 A < 1 s at 24 V DC and room temperature
Average current consumption: (at 24 V DC)	2.7 A
Current peaks with strong blackening of paper:	up to 8 A
Average power consumption:	65 W

ACOUSTIC CHARACTERISTICS

Frequencies of channel 1, channel 2 :

12 kHz
15 kHz
33 kHz
100 kHz
210 kHz

MEASUREMENT ACCURACY

(Requirement: sound velocity set exactly. GAIN: AUTO)

12 kHz: 1 digit ±30.0 cm ±0.1 %. of depth value
15 kHz: 1 digit ±20.0 cm ±0.1 %. of depth value
33 kHz: 1 digit ± 5.0 cm ±0.1 %. of depth value
100 kHz: 1 digit ± 5.0 cm ±0.1 %. of depth value
210 kHz: 1 digit ± 1.0 cm ±0.1 %. of depth value

SMALLEST RECORDABLE DEPTH

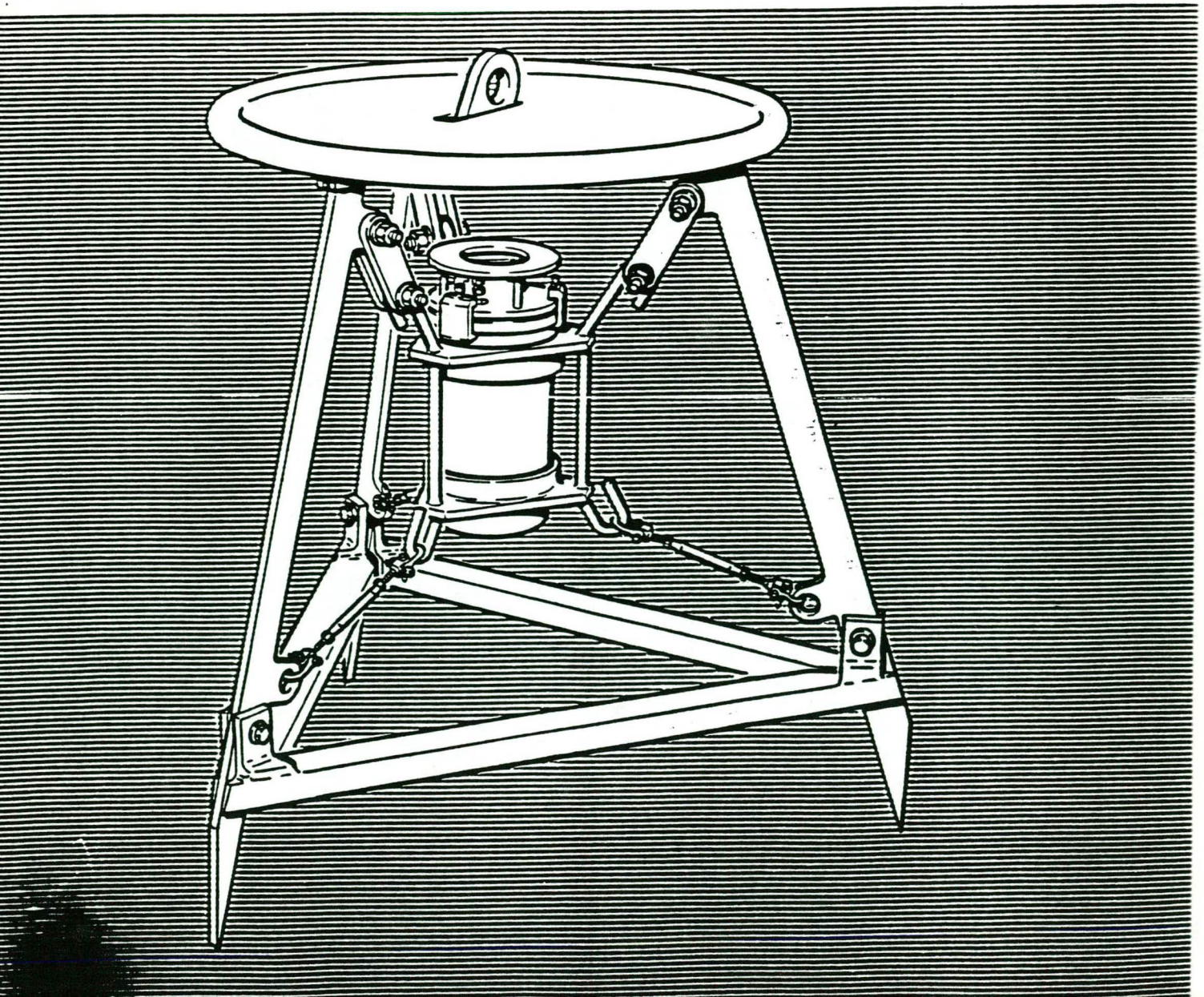
12 kHz	2.0 m
15 kHz	2.0 m
33 kHz	0.6 m
100 kHz	0.6 m
210 kHz	< 0.6 m

ENVIRONMENTAL CONDITIONS

Operating temperature:	-10°C to +55°C at 90 % rel. humidity, no condensation
Storage temperature:	-25°C to +70°C
Vibration:	3 Hz to 12.5 Hz: ±1.6 mm amplitude 12.5 Hz to 50 Hz: 1 g acceleration
Shock:	30 g / 11 ms
Type of enclosure:	IP 22 (drip-proof,with fixed window)
Radio interference suppression grade:	Limiting value class B as per VDE 0871
Noise level at a distance of 1 m (air-borne sound):	< 60 dB

Appendix H

Dag 6000 Bottom Tide Gauge



Appendix I

- Literature
- Low Cost Harbour Surveying by Hans Peter Rohde
- Gathering and Proccessing of Hydrographic Data used for Production of Bathymetric charts by Matthias Lundberg
- Tide Recording by N.B. Webber - Department of Civil Engineering, University of Southampton
- Hydrography for the Surveyor and Engineer by A.E. Ingham
- Admiralty Manual of Tides NP120
- NESA PDS-1000 User Manual(Offline-Modules)
- Atlas Deso 25 Maintenance and Installation Manual